PATENT SPECIFICATION (11) 1 219 515

DRAWINGS ATTACHED

1 219 515

(21) Application No. 59556/68 (22) Filed 13 Dec. 1968
(31) Convention Application No. 741 409
(32) Filed 1 July 1968 in
(33) United States of America (US)
(45) Complete Specification published 20 Jan. 1971
(51) International Classification H 01 c 7/00
(52) Index at acceptance
H1S 2A 2C 3B 5 6A3X 8

(54) ELECTRICAL RESISTORS

(71) We, VISHAY INTERTECHNOLOGY INCORPORATED, a corporation organised under the laws of the State of Pennsylvania, of 63, Lincoln Highway, Malvern, Pennsylvania 19355 U.S.A., do hereby declare the invention for which we pray that a Patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to electrical resistors, and especially to resistors of extremely high precision and stability.

Various attempts have been made in the past to construct high precision resistors of specially prepared wire. Winding the wire on spools introduced problems of short-term and long-term stability of the spools themselves, as to their mechanical and electrical properties. In attempts to obviate spool difficulties, the wire has in some cases been loosely bunched in a container, rather than being wound on a spool. Special alloys have been used, and attempts have been made to minimize the strains in the wire. Problems of strength and permanence of structure arise with such resistors. Furthermore, reactance problems are encountered at high frequencies, because of inductance of the wire, varying with the positioning thereof, and capacitance between portions of the wire.

In United States patent specification No. 3405381 a resistor lement is described which overcomes many of the disadvantages of the best resistors formed of wire. A dielectric substrate, such as a thin glass wafer which may be of the order of one-fourth inch square, is provided with a resistive metallic film in which a relatively long resistive path is established. As therein described, epoxy coatings may be applied to such a substrate, and may be symmetrically disposed to avoid warping tendencies. By taking into account the different temperature coefficients of expansion of the epoxy coatings and the substrate, and appropriately relating thereto the temperature coefficient of resistivity of the resistive metallic film, the resulting uncased resistor element may be made to have an overall temperature coefficent of resistivity of the order of three parts per million per degree centigrade over a wide temperature range such as the range from 25°C to 125°C. Also described in the said United States specification is the encapsulation of such a resistor element in plastics, ceramic, or metal housing, which is impermeable to vapor transmission, to provide a resistor unit, the resistor unit itself being surrounded by a sheath of rubber polyurethane foam or other soft material, the remainder of the space within the housing being filled with a hard filler such as an epoxy.

The resultant encased resistor is characterized by short-term and long-term stability characteristics greatly superior to those or other types of resistors. Along with its extremely low temperature coefficient of resistivity, it possesses stability with respect to the effects of moisture and pressure on the housing which is high enough for many exacting requirements.

It is an object of the present invention to provide resistors of such extraordinary stability with respect to a wide range of ambient conditions and such permanence of characteristics as to be suitable for use as resistance standards and to serve other exacting needs.

The present invention provides a resistor unit comprising a hermetically sealed housing, a resistor element within said housing including a rigid dielectric substrate having a resistive metal film thereon and a pair of flexible leads connected to said resistive film and extending from said substrate, said resistive film having elastic properties which obey Hooke's law in tension and compression, means hermetically sealing said hous-

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ing and affording insulated support for terminal wires of said resistor unit, and an oil medium sealed within said housing surrounding said resistor element and filling most of the enclosed volume.

The resistor element is thus so housed as to isolate it completely from the effects of moisture and variations of pressure on the case. Moreover the transmission of any mechanical forces to the element from the housing is minimized.

The invention will now be described with reference to the accompanying drawings, wherein Figure 1 is an exploded view of parts of a first reactor unit of the present invention and Figure 2 is a detailed view of a part therefor; Figure 3 is a view of the completely assembled first resistor unit; Figure 4 is a cross-sectional view of a second resistor unit arranged to include a plurality of resistor wafer elements; Figures 5 and 6 are an isometric view and a bottom view, respectively, of a multi-cavity dielectric body of the second resistor unit; Figure 7 is an isometric view of a third resistor unit of the invention, a portion of a case thereof being broken away to expose the interior to view; and Figure 8 is an exploded view of the third resistor unit.

Referring now to Figure 1, a metallic cylinder 11 is arranged to receive two end pieces, 13 and 14 (14 not shown in Figure 1), each of which consists of a glass disc having a surrounding metal ring fixed to its periphery by a glass-to-metal seal. Each disc also includes a metal eyelet centrally located therein and bonded to the glass by a glass-to-metal seal. The surrounding metal ring of each disc is arranged to be bonded by solder at its periphery to an end portion of the metal cylinder 11. Preferably, a minute shoulder (not shown) is formed in each end portion of the metal cylinder 11 to facilitate accurate positioning of the end disc with its surrounding metal ring. The central eyelet of each end disc is also arranged to project a short distance from the surface of the glass and is prepared to be bonded by solder to a terminal wire lead of the unit.

As one example of mutually compatible glass and metal materials, borosilicate glass can be used with kovar metal (Kovar is a Registered Trade Mark).

The assembly to be housed within the cylinder 11 between the end discs 13 and 14 consists of a very small printed circuit board 21 upon which is supported, by its flexible leads 15 and 20, a resistor element 22 comprising a rigid dielectric substrate having a resistive metallic film, having elastic properties which obey Hooke's law in tension and compression, affixed thereon. The arrangement and construction of the resistive element 22, arranged for a relatively long conductive path between the junctions of the flexible leads 15 and 20 is described in the aforementioned United States patent specification No. 3405381.

Also fixed to the printed circuit board 21 are wires 26 and 27 which are arranged to serve the dual purposes of supporting the printed circuit board 21, and constituting the ultimate terminal wires or lead wires of the completed resistor.

The enclosure, consisting of the metal cylinder 11 and the end discs 13 and 14 peripherially bonded to the cylinder and centrally bonded to the lead wires 26 and 27, respectively, is almost entirely filled with an oil, a suitable oil for this purpose having been found to be Dow Corning # 200 Silicone Oil. A very small pocket of gas, such as dry air, is provided in order to accommodate differential expansions or contractions of the housing and the oil contained therein.

The steps involved in assembling the resistor system of Figs. 1, 2 and 3 will now be described. Initially, one of the end discs 13 is inserted in the cylinder 11 and its metal ring is soldered in place, making a seal around the periphery. The resistor element 22 is connected to the printed circuit board 21, the end of the flexible lead 15 being soldered to the printed circuit conductor which extends to the lead wire 26, and the end of the flexible lead 20 being soldered to the printed circuit conductor leading to the junction of the lead wire 27. The leads 15 and 20 are bent after being bonded to the respective conductor portions of the printed circuit board 21. Preferably, before inserting the assembly including the resistor element 22, the printed circuit board 21, and the ultimate resistor terminal lead wires 26 and 27 into the cylinder 11, this cylinder is lined with a thin layer of Teflon insulating material (Teflon is a Registered Trade Mark) to insure against any accidental electrical contact between either of the units 21 or 22 and the inner cylindrical wall of the housing.

The lead wire 26 is inserted through the eyelet of disc 13 as the sub-assembly, including the printed circuit board 21 and the resistor 22, is moved to the left and into the interior of the cylinder 11. When the sub-assembly, including the parts 21 and 22, is approximately centrally located within the cylinder 11, a soldered junction is formed between the central eyelet of disc 13 and the lead wire 26, completing hermetic sealing of the left end of the resistor unit.

Next, the opposite end disc 14 is slipped over the terminal lead wire 27 and moved into position in the end of the cylinder 11 opposite the first end disc 13. The peripheral metal ring of end disc 14 is soldered to the cylinder 11 around its entire periphery by dipping this end of the cylinder (along with

the projecting terminal lead wire 27) into a hot solder bath. During this operation, the solder is prevented from bonding the wire 27 to the eyelet of the right hand disc 14 by the heated air escaping through said eyelet from the interior of the cylinder 11.

The unit as thus far assembled has the same appearance essentially as shown in Fig. 3, the only things lacking at this stage being the almost complete filling of oil in the solder junction between terminal lead wire 27 and the eyelet of end disc 14. The structure is then placed within an evacuation chamber in which is a reservoir of the oil. In that chamber, the air contained within the structure is substantially completely exhausted, and by virtue of immersion of the unit in the silicone, restoration of atmospheric pressure causes the silicone oil to be drawn into the housing substantially filling it. Before making the final solder junction between the terminal lead wire 27 and the right-hand end disc 14, the temperature of the unit is elevated to approximately 125°C, at which temperature the silicone is expanded to a greater than normal volume. Thereafter, cooling of the unit to room temperature results in the ingress of a very small amount of air, to provide the desired pocket for expansion and contraction. The product is completed by forming the solder junction between the terminal lead wire 27 and the eyelet of end disc 14.

For some ranges of resistance, and for increased heat dissipation capacity, it is desirable in some instances to use several resistor elements within the housing defined by cylinder 11 and end discs 13 and 14. In Figures 4, 5 and 6, the second illustrative resistor unit is illustrated wherein there are provisions for connecting three separate resistor elements 22′, each like the resistor element 22 in Figure 1, in a series and housing them within the oil bath in the enclosure defined by cylinder 11 and end discs 13 and 14. For this purpose, a block 41 of plastics material having a plurality of cavities 42, 43, and 44, may be provided and so arranged as to be inserted within the metal cylinder 11. The block 41, shown in cross-section in Figures 4, 5 and 6 provides for the positioning of a plurality of the resistor elements 22′ in respective ones of its cavities, and for the connection of their respective flexible leads through holes in the bottom of the block 41 to a pattern of printed circuit conductors on the bottom of said block (see Figure 6). As shown in Figure 6, the pattern of conductors on the bottom of the block 41 may be so arranged as to cause the plurality of resistor elements 22′ to be connected in series with each other between the left hand terminal lead wire 26 and the right hand terminal lead wire 27.

The internal dimensions of the cavities 42, 43 and 44 are substantially greater than the dimensions of the respective resistor element. Accordingly, when each resistor element 22′ is properly positioned and installed within its cavity of the block 41, it is surrounded entirely by oil, and is free from any mechanical forces exerted by the block 41 or any portion of the enclosure's cylindrical or end parts.

In Figures 7 and 8 is shown the third illustrative resistor unit in accordance with this invention. A single-cavity of a container 51 which is made of plastics material is arranged to accommodate a single film-on-substrate wafer resistor element 22, the cavity again being substantially larger in all its dimensions than the dimensions of the resistance wafer element. The housing for the resistor element of Figures 7 and 8 comprises a relatively narrow metal housing 52 open only at its lower end, and an end closure unit 53 comprising a glass body 54 having two eyelets 56 and 57 bonded thereto by glass-to-metal seals, along with a peripheral metal band 58 also joined to the glass in a glass-to-metal seal.

In this form of resistor unit, terminal lead wires 26′ and 27′ are both extended downward from the bottom of the resistor element parallel to each other.

The single-cavity body 51, unlike the block 41 of the second illustrative resistor unit does not include a printed wiring pattern and relies instead upon mere passages or bottom holes through which the resistor terminal lead wires extend.

The unit of Figures 7 and 8 is made up by first bonding the ends of the relatively short flexible leads 15 and 20 from the film-on-substrate resistor element 22 to the upper ends of the terminal lead wires 26′ and 27′. These terminal lead wires are then passed downward through the cavity of the molded body 51, and extended through the holes in the bottom of said body. The terminal lead wires 26′ and 27′ are then passed through the metal eyelets 56 and 57 which are sealed to the glass 54 of the end closure unit 53.

A very small layer of Teflon (RTM), or other suitable insulating material (not shown) is inserted within the metal housing 52 and made to lie against the closed end thereof. The molded body 51 having the resistor wafer element 22 enclosed therein is moved up into the interior of the housing 52, and the end closure unit 53 is next brought into a position on the lower end of the housing 52, where it is ready to be soldered in place.

The unit is then soldered by dip soldering, to form a continuous and complete bond between the lower end of the housing 52 and the metal ring 58 bonded to the periphery of the lower end closure unit 53 and forming a part thereof. In this dip-soldering

process, one of the eyelets in the lower end of the closure unit will be solder-bonded to the terminal lead wire passing therethrough, but the other will be kept open by air emerging due to the rising temperature within the housing 52. Again, the process of substantial evacuation is followed by filling with the silicone filler at the elevated temperature, after which the silicone contracts leaving a small void sufficient to allow for the differential expansion and contraction of the case and the silicone filling. The final step is soldering of the open eyelet to the terminal lead wire passing therethrough.

We have found the first, second and third illustrative resistor units are more capable of standing shock and vibration than any of the loosely wound wire precision resistors, and are at least as good as the spool-wound precision resistors. In contrast to both such types of wire resistors, each of the illustrative units has a minimum of reactive effect, its inductance being typically as low as or lower than 1/10th microhenry, and its distributed capacitance being typically as low as or lower than 1/2 micro microfarad. By virtue of such extremely low reactance factors, a resistor unit in accordance with the present invention remains at a substantially unity power factor at frequencies far greater than at the frequencies up to which the resistors constructed of wire may be used, with or without attempts at inductance cancellation arrangements.

Whereas, the prior form of wafer resistor, embedded in a soft cushion which in turn is within an epoxy filling in a case having epoxy end seal or seals, has some susceptibility to moisture effect and to variations of pressure of the medium (frequently the atmosphere) in which the resistor is used, we have found that a resistor unit in accordance with the present invention is rendered independent of surrounding moisture (even steam under pressure) and independant of pressure of the surrounding medium. The former type of encased wafer resistor, with its resistive film path, could have as much as 50 ppm change of resistance due to change of pressure, and as much as 400 ppm change of resistance with moisture under extremely adverse conditions. In contrast, a resistor unit in accordance with the present invention demonstrates insufficient change of resistance in response to either of these effects to be measurable with extremely sensitive measuring equipment.

Also, while the change of resistance value with ageing (for example, ageing on the shelf) is less for the previously described epoxy-sealed resistor from that which applies to an un-encased wafer resistor, a resistor unit constructed in accordance with the present invention demonstrates such extraordinary freedom from a drift with ageing as to show no measurable amount on equipment arranged for checking to the resolution of one ppm. In this respect, also, a resistor unit in accordance with the present invention not only is at least an order of magnitude better than the encased wafer resistor heretofore developed, but also is an order of magnitude better than the precision resistors which have been made using specially prepared wire, either loosely inserted or spooled.

A resistor unit, in accordance with the present invention, can be used as a standard resistor.

WHAT WE CLAIM IS:—

1. A resistor unit comprising a hermetically sealed housing, a resistor element within said housing including a rigid dielectric substrate having a resistive metal film thereon and a pair of flexible leads connected to said resistive film and extending from said substrate, said resistive film having elastic properties which obey Hooke's law in tension and compression, means hermetically sealing said housing and affording insulated support for terminal wires of said resistor unit, and an oil medium sealed within said housing surrounding said resistor element and filling most of the enclosed volume.

2. A resistor unit according to claim 1, wherein said hermetically sealed housing is cylindrical and said terminal wires extend axially in opposite directions from said housing, said means hermetically sealing said housing including a pair of end closure units each comprising a glass disc having a central aperture and provided with peripheral and central metal-to-glass seals.

3. A resistor unit according to claim 1, wherein said housing is open at one end and said means for hermetically sealing said housing comprises a glass body through which extend said terminal wires.

4. A resistor unit according to claim 1, comprising a metal housing, two resistor terminal conductors extending outward from said housing and insulated therefrom, means for hermetically sealing at least one end of said housing and affording insulated support for said resistor terminal conductors, said means including a glass portion sealed to the housing at said or each end by metal-to-glass seals both at its periphery and at the point of support of each of the resistor terminal conductors.

5. A resistor unit substantially as hereinbefore described with reference to:—

a) the first illustrative resistor unit;
b) the second illustrative resistor unit;
or c) the third illustrative resistor unit.

ERIC POTTER & CLARKSON,
Chartered Patent Agents,
Kingsway House,
103 Kingsway,
London, WC2B 6QX.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1970
Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY from which copies may be obtained

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

FIG. 1

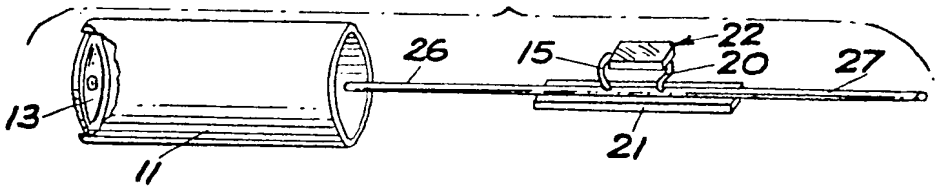


FIG. 2.

FIG. 3

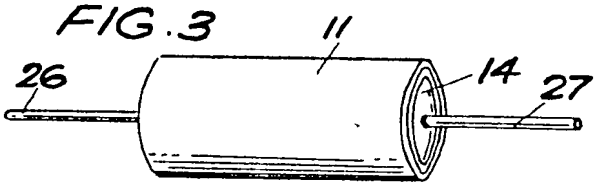


FIG. 4

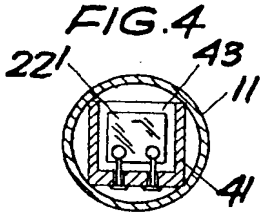


FIG. 5

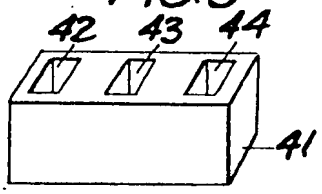


FIG. 6

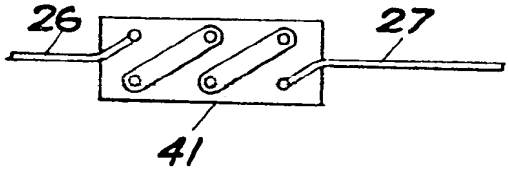


FIG 7

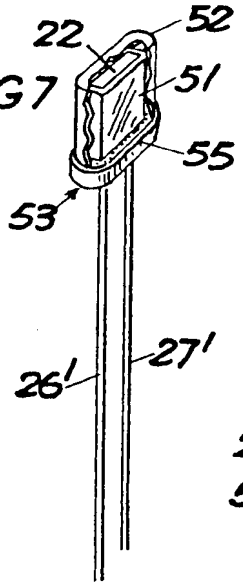
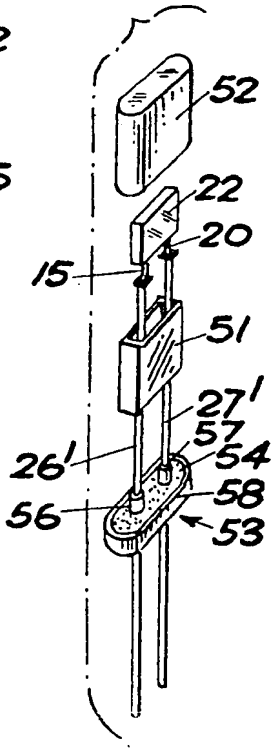


FIG. 8.



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APPLICANT: Gross

LEHRER [illegible]ENBERG P.A.

[illegible]180

HOLLY[illegible]IDA 33022

TEL. (954) [illegible]25-1100

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établi sur la base des dernières revendications déposées avant le commencement de la recherche

N° d'enregistrement national

FA 609088
FR 0113446

DOCUMENTS CONSIDÉRÉS COMME PERTINENTS		Revendication(s) concernée(s)	Classement attribué à l'invention par l'INPI
Catégorie	Citation du document avec indication, en cas de besoin, des parties pertinentes		
X	DE 42 04 582 A (MURATA MANUFACTURING CO) 3 septembre 1992 (1992-09-03)	1	H01C1/148 H01C1/028
X	* colonne 2, ligne 15-65; figure 2 *	1	
A	* le document en entier *	2-7	

A	US 1 828 577 A (HAROLD PENDER) 20 octobre 1931 (1931-10-20) * le document en entier *	1-7	

A	GB 1 206 143 A (VIDEOTON RADIO ES TELEVIZIOGYAR) 23 septembre 1970 (1970-09-23) * le document en entier *	1-7	

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A	US 3 169 237 A (THOM MCLVIN A) 9 février 1965 (1965-02-09) * le document en entier *	1-7	
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Document brevet cité au rapport de recherche		Date de publication	Membre(s) de la famille de brevet(s)		Date de publication
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LERNER AND GREENBERG P.A.
P.O. BOX 2480
HOLLYWOOD, FLORIDA 33022
TEL. (954) 925-1100